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# Short-term planning and forecasting for petroleum

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# NAVAL POSTGRADUATE SCHOOL
# Monterey, California

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SHORT-TERM PLANNING AND FORECASTING
FOR PETROLEUM

by

Ronald D. Elkins

June 1988

Thesis Advisor: Alan W. McMasters

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# Short-Term Planning and Forecasting for Petroleum

by

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Submitted in partial fulfillment of the
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## ABSTRACT

The Defense Fuel Supply Center (DFSC) has, in recent past, been unable to adequately forecast for short-term petroleum requirements. This has resulted in inaccurate replenishment quantities and required short notice corrections which interrupted planned resupply methods. The relationship between the annual CINCLANTFLT DFM budget and sales from the Norfolk Defense Fuel Support Point (DFSP) is developed and the past sales data from the Norfolk DFSP is used to construct seasonality indices. Finally, the budget/sales relationship is combined with the seasonality indices to provide a new forecasting model. This model is then compared with the current one for FY-88 monthly forecasts. The comparison suggests that the new model can provide accurate, timely requirements data and improve resupply of the Norfolk Defense Fuel Support Point.

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# I. PETROLEUM REQUIREMENTS FORECASTING PROBLEMS

## A. THE PROBLEM

Petroleum is one of the most expensive items of material support procured by the Department of Defense. It is also one of the least understood commodities managed by DOD. For fiscal year (FY) 1986 the Defense Logistics Agency (DLA) procured materials valued at $16.7 billion dollars, of which $9.5 billion was for consumable petroleum products. Petroleum accounted for 57.2 percent of all DLA procurements in FY-86 with all of the top 25 total dollar value contracts awarded by DLA being petroleum related. [Ref. 1]

The lack of access to Petroleum-Oils-Lubricants (POL) can cause the operational failure of a Naval Battle Group (conventional or nuclear) and its assigned air wings. The failure of the battle group's primary mission could be due to either the lack of petroleum in adequate quantity or quality. This failure could occur without the battle group ever engaging the enemy.

The Norfolk Defense Fuel Support Point (DFSP) is the largest Navy operated fuel terminal in the Continental United States. It is comprised of three separate fuel terminals located at Craney Island and Sewells' Point in Norfolk, and a third terminal at Yorktown, Virginia. The DFSP has a total petroleum storage capacity of 160 million

gallons of which approximately 57 million gallons is dedicated to the storage of Marine Diesel Fuel (DFM). Annual sales for the DFSP are approximately 384 million gallons. [Ref. 2]

The Navy's annual forecast for DFM requirements has historically been very close to the actual sales from the DOD wholesale petroleum operations to the Navy retail operations. [Ref. 3] The execution of the annual Navy DFM budget, however, has caused a significant short-term requirements problem for the DOD wholesale inventory management system. This problem is a consequence of poor forecasting for the short term wholesale bulk petroleum requirements. [Ref. 4] A review of the problems encountered in 1987 with management of DOD DFM inventories and accuracy of forecasting for short-term DFM requirements follows.

1. <u>Defense Fuel Supply Center</u>

On 6 August 1987, the Defense Fuel Supply Center (DFSC) became concerned over the levels of East Coast DFM sales for the period of April to July, 1987. Actual sales of DFM had exceeded the forecasted amounts by 50 percent and were above the prorated contract quantities. [Ref. 5] The monthly prorata contract amount is the forecasted annual sales for an area divided by 12. [Ref. 6] It is the monthly production quantity requested in the procurement contract. If this quantity is not delivered in a given

month, it is not usually available to the government for procuring at a later time. [Ref. 6]

2. Department of Defense Inspector General

On 22 October, 1987, during an inspection of DFSC the DOD Inspector General (IG) concluded:

> Defense Fuel Supply Points (DFSPs) and Defense Fuel Supply Center (DFSC) inventory managers do not receive timely, accurate bulk fuel replenishment data from the Navy fleet units so that DFSC can resupply fuel terminals as necessary and at the most economical cost to the Government. [Ref. 4]

Additionally, the DOD-IG found:

> Neither DOD nor the Navy have designated responsible activities to provide fleet unit consumption forecasts supporting DFSP or DFSC inventory managers. [Ref. 4]

3. Naval Petroleum Office

As the functional manager for the DFSPs operated by Naval Supply Centers (NSCs) the Naval Petroleum Office (NAVPETOFF) became concerned in the spring of 1986 by the increased demand for DFM along the East Coast. The increased consumption had seriously reduced the DFM inventory stock position of the DFSPs. The problem was compounded by a lead time of three to four weeks for emergent requirements, and two months for normal inventory replenishment [Ref. 7] so that "by the time the demand surge became evident little could be done." [Ref. 8]

In addition, Puerto Rico Sun, a petroleum refinery under DFSC contract and the major supplier of DFM for support of the East Coast and the Norfolk DFSP, was unable to produce its prorata quantity for May, 1987 [Ref. 8],

which further contributed to the East Coast DFM shortage problem.

## B. THE CAUSES

A post hoc analysis of the causes contributing to the inability of the high DFM sales requirement to be adequately forecasted was initiated. The various DLA and Navy commands involved in wholesale bulk petroleum management and requirements forecasting reviewed the problem during the summer of 1986 and excerpts from their findings are presented here.

### 1. Defense Fuel Supply Center

DFSC's position was that the increase in East Coast DFM requirements above the forecasted and prorata levels was attributable to the DFSP's not forecasting the correct short-term DFM requirement volumes. DFSC was therefore not prepared to adequately respond to the high demand volumes through normal resupply methods. [Ref. 9]

### 2. Naval Petroleum Office

NAVPETOFF's review of the increased East Coast DFM requirement resulted in a recommendation that a relationship might be identified between the DFM budget of the Commander-in-Chief, Atlantic Fleet, and DFSP sales. Perhaps this might provide a "good 'macro' indicator of East Coast (DFM) consumption." [Ref. 10]

Additionally, NAVPETOFF reviewed the short-term wholesale bulk petroleum requirements forecasting

procedures. Continental United States (CONUS) short-term forecasting covers the moving period spanning the current and three future months (4 months). [Ref. 11:p. II-4-15] For example, period one would be Jan-Feb-Mar-Apr and period two would be Feb-Mar-Apr-May. The four-month period is established by the requirements of processing for the CONUS SLATE, the slate being the actual report of wholesale bulk petroleum requirements. [Ref. 11]

Processing of forecasts for requirements for the Norfolk DFSP are done by the Defense Fuel Region Northeast (DFR-NE). [Ref. 11:p. II-4-57] NAVPETOFF's finding was as follows:

> A review of the slating practices has revealed that no CONUS region standard slating procedures exist for DFSPs. Actual practice differs...in the Northeast Region, NSC Norfolk telefaxes on a monthly basis a slated forecast of requirements for the ensuing 120 day period. Again no documentation feedback is provided the terminal operator.... [Ref. 10]

3. Defense Fuel Region Northeast

Defense Fuel Region Northeast, in a review of the increased DFM sales at the Norfolk DFSP, indicated that regional slate forecasting for short-term petroleum requirements was based on the following elements: [Ref. 12]

- Regional Inventory Levels.
- Pipeline Delivery Capability.
- Contract Coverage.

The forecasted DFM requirements in support of the Norfolk DFSP are coordinated between DFR-NE, DFR-SW and DFSC

Operations (DFSC-OI). [Ref. 12] The 4-month moving window of the slate is intended to act as a refinement of the requirements. The slate is processed by the DFSPs and DFRs and is to be received by DFSC "on or before the 10th calendar day of each month." [Ref. 11:p. II-4-16] This data needs to be as accurate as possible due to the commitment of transportation modes.

> Since shipping and ordering arrangements are normally made 30 to 60 days in advance of delivery dates, shipping instructions for the current and following month will have been issued prior to the receipt of the current slate. Therefore, maximum effort must be made to ensure that changes in slated requirements for the first two months be held to a minimum consistent with operational necessity. [Ref. 11:p. II-4-15]

The Norfolk DFSPs' 90-day projection for May, 1987 was 200 MBBL (M = 1,000, BBL = barrels). [Ref. 11:pp. II-1-36--II-1-38] When the current month May slate was submitted this quantity had risen to 400 MBBL. The Norfolk DFSP was finally resupplied with 430 MBBL during May, 1987. [Ref. 12]

DFR-NE documentation established that "As deliveries are confirmed, DFSP Norfolk receives the information either verbally or by letter, memo or tanker schedule." [Ref. 12] This vagueness in reporting procedures would support the NAVPETOFF position that there is a problem with the timely notification of the DFSPs as to when and how resupply of the terminals will occur. [Ref. 10]

4. Norfolk Defense Fuel Support Point

The Norfolk DFSP, in a recap of the events which led up to the DFM shortage along the East Coast in the spring and summer of 1987, indicated that it was DFSC policy to allow Norfolk DFSP inventory levels to "fluctuate between 32 percent and 100 percent in order for the petroleum resupply system to work efficiently." [Ref. 13] The DFRs manage inventory levels by region, while the DFSPs are concerned with local inventory levels and requirements. [Ref. 11:p. II-10-6.2] At the same time NSC Norfolk, the command exercising operational control over the Norfolk DFSP, had established an inventory stockage objective policy of 80 percent of authorized inventory capacity. [Ref. 13]

Forecasted requirements of DFM to be sold from the Norfolk DFSP in August, 1987 were predicted to reduce the inventory position to 29 percent. [Ref. 13] The reduction in on-hand inventory was to result from the issue of DFM to Second Fleet units.

The declining East Coast DFM wholesale inventory stock position, and its potential impact on Second Fleet operational readiness, required immediate corrective action to reestablish the stock levels. The actions listed below were taken to correct the reduced DFM inventory position.

- Transfer of DFM stocks from other DFSPs within the CINCLANTFLT Area of Responsibility (AOR).
- Accelerated receipt (lifting) of DFM from East and Gulf Coast refinery production contracts (DFSC).

- Receipt (lifting) of 2 tanker cargoes of DFM from the DFSC refinery production contract with Motor Oil Hellas, Athens, Greece. [Ref. 9]

- Award of a supplemental solicitation (DFSC) for 1600 MBBL of DFM. Half of the emergent requirement to rebuild East Coast DFM inventory levels was for delivery to the Norfolk DFSP during the months of August to September 1987. [Ref. 5]

In summary, the short-term wholesale requirements forecasting procedures in use were not anticipating the actual demand. Slated quantities were inaccurate and required short notice correction which resulted in interruption of planned resupply methods. Continued use of the current forecasting procedure could result in a recurrence in 1988 of the DMF shortage experienced in 1987.

## C. OBJECTIVE

The objective of this thesis is to develop a forecasting model which can hopefully provide a more accurate short-term wholesale bulk requirements forecast for the Norfolk DFSP DFM sales.

## D. SCOPE

This thesis will concentrate on a 12 month forecasting model for wholesale bulk DFM requirements in support of the Norfolk DFSP. Due to the scope of petroleum products managed by the Department of Defense, this thesis will be limited to review of requirements forecasting for Diesel Fuel Marine (DFM) in support of the Norfolk Defense Fuel Support Point (DFSP). The ability to forecast DFM demand

for a 12-month period will meet the DOD IG requirement for timely, accurate requirements forecasting. [Ref. 4] Review of the requirements forecasting process for wholesale bulk DFM will be limited to an analysis of the relationship between the annual CINCLANTFLT DFM budget to the actual annual DFM sales from the Norfolk DFSP.

## E. METHODOLOGY

The research effort for this thesis was three-pronged. Initially the author reviewed correspondence and records relating to the East Coast shortage of DFM during the spring and summer of 1987. This was followed by a review of literature governing the general military management of wholesale bulk petroleum inventories and requirements forecasting. Next, interviews were conducted with personnel working in both wholesale bulk petroleum inventory management and requirements forecasting. Interviews were conducted both personally and by telephone. The author also visited petroleum activities to gather data relative to the DFM shortage and requirements forecasting problems. Commands visited included DFSC, NAVPETOFF, CINCLANTFLT, NSC Norfolk, and the Norfolk DFSP.

The selection of the Norfolk DFSP for concentrated study was motivated by its position as the largest DFSP in the Continental United States (CONUS) and its function as the primary source of DFM to the Second Fleet.

## F. PREVIEW

Chapter II will review the DOD, DLA, DFSC, and Navy instructions governing the general military management of wholesale bulk petroleum inventories. Attention will be directed to requirements determination and inventory management. Chapter III will be concerned with the development of a proposed seasonality index model to predict monthly DFM requirements at the Norfolk DFSP. It will consider the level of historic DFM sales at the Norfolk terminal and CINCLANTFLT Second Fleet DFM demand from the Norfolk DFSP. Chapter IV will evaluate the ability of the seasonality index model to provide timely, accurate forecast requirements. This analysis will be completed using two methods. First, the ability of the seasonality index model to maintain satisfactory DFSP inventory levels will be evaluated. Second, a comparison will be made between the current and proposed forecasting models. Chapter V will present a summary, conclusions, and recommendations for possible action.

## II. PETROLEUM INVENTORY MANAGEMENT REVIEW

### A. INTRODUCTION

This chapter presents the context of the regulations governing POL inventory management and the 1987 forecasts and sales. It will serve as a reference point for the next chapter which will examine an alternate method of calculating short-term wholesale bulk petroleum (DFM) requirements in support of the Norfolk DFSP. Quantities are in Mike (M) barrels (BBL). A barrel of petroleum equals 42 U.S. gallons, and 1,000 barrels equal 1 Mike barrel (MBBL). [Ref. 11:pp. II-1-36--II-1-38]

Forecasting for short-term wholesale bulk petroleum requirements is critical to satisfactory inventory management operations of a DFSP and the operational readiness of the units supported. The Norfolk DFSP experiences an average DFM inventory turnover of four times annually (1350 MBBL authorized capacity and 5581 MBBL annual sales 1987). [Ref.14] This is a DFM inventory stock turn of once every three months.

To better understand how short-term wholesale bulk petroleum forecasting should be accomplished it is necessary to examine government regulations which control the inventory management of petroleum. The regulations governing the short-term wholesale bulk petroleum inventory

management will be reviewed through the Petroleum-Oils-Lubricants (POL) chain-of-command.

## B. WHOLESALE PETROLEUM INVENTORY MANAGEMENT RESPONSIBILITIES

Inventory management policy applicable to all DOD activities is set out in DOD Directive 4140.1. Its purpose is to establish policy for the management of all inventories of military materials.

The Department of Defense has established Inventory Control Points (ICPs) as:

> An organizational unit within the supply system of a military service which is assigned the primary responsibility for the management of a group of items, either within a particular service or for the Department of Defense as a whole, including computation of quantitative requirements, the authority to require procurement or initiate disposal, development of worldwide quantitative and monetary inventory data, and the positioning and repositioning of material. [Ref. 15]

The following sections will discuss the role of key agencies in the wholesale petroleum management process.

### 1. Defense Logistics Agency

The ICP responsibilities for management of wholesale bulk petroleum products is assigned to the Defense Logistics Agency.

> The Defense Logistics Agency (DLA) was established as the Integrated Material Manager (IMM) for petroleum on 1 July 1973. Ownership of wholesale stocks of petroleum was transferred from the Military Services to DLA on that date. Since many of the Navy's petroleum facilities were considered wholesale activities, DLA now owns the fuel at these locations. [Ref. 16:p. 3-3]

### 2. Defense Fuel Supply Center

The agent which acts for DLA in the execution of its ICP and IMM responsibilities is the Defense Fuel Supply Center (DFSC). DFSC is tasked in this function as follows:

> The Commander Defense Fuel Supply Center (DFSC) has been delegated the coordinated procurement responsibility for all petroleum products...and is designated the integrated material manager for wholesale bulk petroleum products until their delivery to the point of sale.... [Ref. 15:p. I-1-13]

The DFSPs are responsible to DFSC for the petroleum inventories held in their custody. For the purpose of this thesis, DFSPs are operated under DFSC as one of two types: [Ref. 15:p. II-8-1]

- GOGO: Government owned--Government operated.
- GOCO: Government owned--Contractor operated.

The responsibility for operation of the DFSPs is assigned as follows:

> DFSC is responsible for...controlling GOGO and GOCO CONUS terminal inventories by effecting resupply to CONUS DFSPs to assure inventories are maintained between minimum and maximum inventory levels established in the IMP (Inventory Management Plan).... [Ref. 15:p. II-10-4]

### 3. Defense Fuel Regions

The wholesale bulk petroleum management responsibilities assigned to DFSC have been delegated to component activities known as Defense Fuel Regions (DFRs).

> The maintenance of established levels for the terminals storing DLA-owned product is the responsibility of the fuel region. Terminal operators will receive, through appropriate DFSC channels, the inventory levels which are to be maintained. The fuel region will provide necessary instructions concerning receipts and shipments.... [Ref. 15:p. I-2-5]

The calculation of the resupply requirements for the Continental United States (CONUS) DFSPs is accomplished by the DFRs using a short-term forecast report termed the petroleum SLATE. [Ref. 15:p. II-4-15] The method currently used by DFR Northeast is to compare short-term petroleum requirements from DFSP Norfolk against regional inventories, pipeline delivery capability and contract coverage. [Ref. 12] Corrective actions are accomplished as increased levels of DFM requirements become known. Often this increased petroleum requirement has not entered the slating system until the beginning of the month of its required delivery to the DFSP. [Ref. 12] This late entry of requirements into the resupply system results in costly changes in the shipping and ordering arrangements for current month cargos. DFSC completes shipping and ordering arrangements 30 to 60 days in advance of required delivery dates. [Ref. 11:p. II-4-15]

4. Naval Petroleum Office

The senior petroleum activity within the Department of the Navy is the Naval Petroleum Office (NAVPETOFF). NAVPETOFF was initially established in 1952 as the U.S. Navy Fuel Supply Office. The Naval Petroleum Office is assigned as the Deputy Commander, Naval Supply Systems Command, for the Navy Fuel Management System. [Ref. 17]

> The mission of the Naval Petroleum Office, Alexandria, Virginia, is to provide technical direction for petroleum programs within the Navy, including facilities management and storage utilization, technical operations, quality

surveillance, facility automation, and Oily Waste Handling and Pollution Abatement Programs; determine Navy fuel supply requirements. [Ref. 18]

In this capacity the Commanding Officer of NAVPETOFF exercises fuel functional management responsibility over the eight DFSPs operated by Naval Supply Centers (NSCs). [Ref. 17] The mission of NAVPETOFF is further outlined as:

Review, analyze and comment on Navy product requirements, levels, and location in the DFSC Inventory Management Plan (IMP). Coordinate changes in products and levels to be stored at NAVSUPSYSCOM (Naval Supply Systems Command) terminals with DFSC. [Ref. 18]

As the senior command for petroleum management within the Navy, and as the functional manager over the eight Navy (NSC) operated DFSPs, NAVPETOFF is tasked to manage DLA inventories within the levels set in the Inventory Management Plan (IMP). The inventory management is to be on a non-reimbursable basis. [Ref. 11:p. II-8-5]

NAVPETOFF is tasked with the annual requirements determination of wholesale bulk petroleum. This annual forecast has historically been very accurate. [Ref. 3] The levels of annual petroleum requirements and the anticipated price levels are input to the annual Navy budget. Barring price changes, the annual petroleum requirement forecast would be expected to be very close to the actual quantity of petroleum procured with budget dollars. This results as a consequence of the DOD standard price and pricing guidance for petroleum products [Ref. 19] being published in September of each year with the new fiscal budget. However,

the Navy petroleum quarterly budget allocation needs to change rapidly to correspond to shifts in Fleet operational schedules (OPSKEDs). Obviously, it is these fluctuations in Fleet operations which must be considered when evaluating a forecasting model for the short-term wholesale bulk petroleum requirements.

5. <u>Norfolk Defense Fuel Support Point</u>

The DFSP managed by NSC Norfolk is operated as a GOGO petroleum terminal under the inventory control of DFSC.

> ...Operators of GOGO terminals storing DLA-owned product will notify the applicable DFR by message if projected inventory positions indicate that the minimum levels will be reached (and the date when the minimum level will be reached). The DFSC, upon notification by the DFR, will take action to effect resupply to preclude inventories from reaching the minimum level or request a waiver or temporary relocation of PWRMRP (Pre-Positioned War Reserve Material Requirements Protectable) from the applicable Military Service. If the terminal operator does not receive a response indicating which of the aforementioned actions have been taken, and inventories reach the minimum level, routine shipments (to end users) are to be discontinued.... [Ref. 11:p. II-10-6.3]

## C. NORFOLK DFSP SALES VERSUS FORECAST

Beginning in the spring of 1987 the East Coast DFSPs experienced DFM sales (demands) which rapidly drew down the inventory stock position. This excessive demand continued through September of 1987. The forecasted and actual sales quantities for DFM sold from the Norfolk DFSP during the period from October, 1986 to September, 1987 are shown in Table 1 and in Figure 1. [Ref. 8]

TABLE 1

NORFOLK DFSP DFM FORECASTED AND ACTUAL DEMANDS
FROM AUGUST 86 TO MAY 87 (MBBL)

| | 1986 | | | 1987 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
| FORECAST DEMAND | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 |
| ACTUAL DEMAND | 499 | 395 | 458 | 364 | 207 | 529 | 373 | 546 | 427 | 663 | 624 | 496 |

From Table 1 it can be seen that the DFM demand for the 12 month period exceeded the forecast. The monthly requirements forecast had averaged only 64.50 percent of the actual sales. At only one time (in February, 1987) did the forecast exceed the actual sales, and only by 93 MBBL. The negative difference between the actual and forecasted sales levels of DFM in the spring and summer of 1987 serves only to highlight a problem which already existed.

## D. SUMMARY

Inventory management and control (IMM and ICP) for DLA owned petroleum inventories is clearly established as the responsibility of the Defense Fuel Supply Center (DFSC) and its subordinate Defense Fuel Region activities. The Navy is tasked with the operational control of the eight DFSPs operated by the Naval Supply Centers (NSCs).

The current forecasting ability of the DFSC is inadequate. Even if the Navy estimate of wholesale bulk

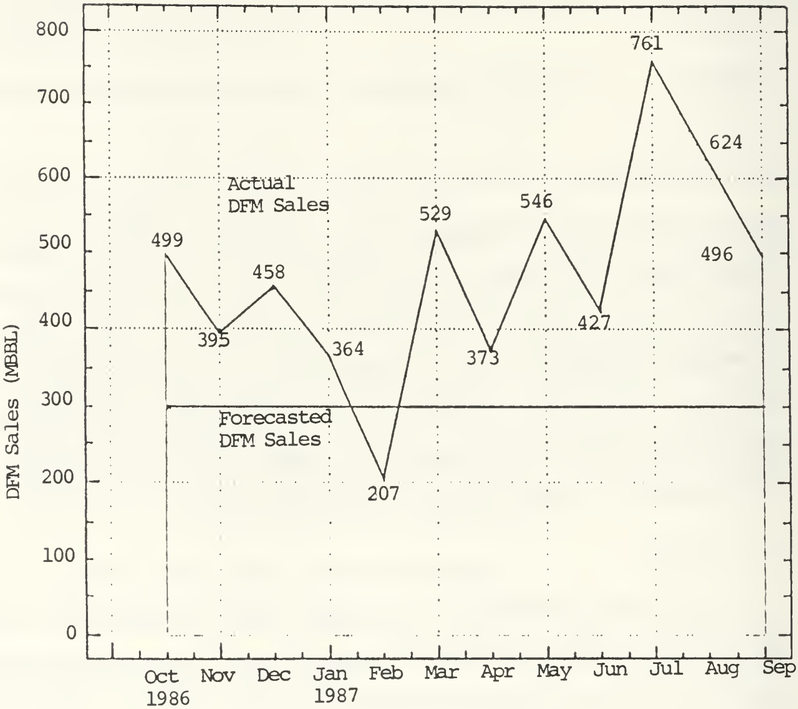


Figure 1. Forecasts Versus Actual Sales
at Norfolk DFSP

petroleum (DFM) requirements can accurately be established on an annual basis, the inventory shortages of DFM on the East Coast in the Spring and Summer of 1987 emphasizes the need for a better method for the forecasting of regional short-term wholesale bulk petroleum requirements.

The next chapter proposes an improved forecasting method for short-term DFSP wholesale bulk petroleum demands.

# III. A PROPOSED FORECASTING MODEL FOR NORFOLK DFSP

## A. INTRODUCTION

This chapter will present the details of the proposed forecasting model for DFM furnished by the Norfolk DFSP. The first part of the chapter develops a relationship between the annual CINCLANTFLT DFM budget and sales at Norfolk. The second part examines past sale data from Norfolk and from it develops a monthly seasonality index. Finally, the budget/sales relationship is combined with the seasonality indices to provide a new forecasting model.

## B. CINCLANTFLT DFM BUDGET

The Commander-in-Chief, Atlantic Fleet (CINCLANTFLT) forces are comprised of Second and Sixth Fleet units. The Second Fleet is composed of afloat units operating along the Atlantic Coast. This includes the East Coast of the United States south to the Caribbean. Support for the Second Fleet is derived from the CINCLANT, NATO Northern Command, commercial bunker sources, and East Coast Defense Fuel Regions. The Sixth Fleet operates as deployed units within the Mediterranean. Petroleum support for the Sixth Fleet is provided through the NATO Southern Command petroleum system or commercial bunker contracts established by DFSC.

The primary afloat customers for DFM furnished from the Norfolk DFSP are Second Fleet units not operating on

extended operations. The CINCLANTFLT Second Fleet DFM budget supports all non-deployed afloat assets operating in the Atlantic littoral. The CINCLANTFLT Second Fleet budget allocations for FY-82 through FY-87 are shown in Table 2. [Ref. 20] Only annual totals are available for the fiscal years 1982 and 1983. As petroleum inventory operations are conducted in barrels (and gallons), vice dollar amounts, the CINCLANTFLT budget will be expressed in the equivalent units of barrels.

TABLE 2

CINCLANTFLT SECOND FLEET ANNUAL DFM BUDGET (MBBL)

| FY | QUARTER 1 | QUARTER 2 | QUARTER 3 | QUARTER 4 | TOTAL |
|---|---|---|---|---|---|
| 82 | | | | | 7,098.0 |
| 83 | | | | | 7,156.0 |
| 84 | 2,087 | 2,020 | 2,202 | 1,711 | 8,020.0 |
| 85 | 1,584 | 1,563 | 2,020 | 2,655 | 7,822.0 |
| 86 | 1,721 | 1,720 | 1,752 | 2,008 | 7,201.0 |
| 87 | 1,649 | 1,774 | 2,093 | 2,376 | 7,892.0 |

As can be seen from Table 2 the CINCLANTFLT annual DFM budget allocation for the fiscal years shown has increased from approximately 7,100 MBBLs in 1982 to 8,000 in 1984, then down to 7,200 in 1986 and back up to 7,900 in 1987. The variation is a function of the budget level and allocation of petroleum between the Second and Sixth Fleets.

The mean annual DFM budget for the Second Fleet is 7,531.5 MBBL with a range of 922 MBBL.

## C. DFSP NORFOLK, VIRGINIA

The Norfolk DFSP is located in Norfolk, Virginia and is operated as a department of the Naval Supply Center (NSC), Norfolk. The main terminal is located at Craney Island, with smaller terminals located at Sewells' Point on the main Naval Base, and further up the James river at Yorktown, Virginia. [Ref. 2]

The quarterly and annual sales of DFM from the Norfolk DFSP for the period of FY-82 through FY-87 are shown in Table 3. [Ref. 14]

TABLE 3

NORFOLK DFSP DFM SALES (MBBL)

| FY | QUARTER 1 | QUARTER 2 | QUARTER 3 | QUARTER 4 | TOTAL |
|---|---|---|---|---|---|
| 82 | 1,003 | 749 | 886 | 656 | 3,294 |
| 83 | 662 | 1,014 | 1,127 | 1,136 | 3,939 |
| 84 | 717 | 1,103 | 1,064 | 1,159 | 4,243 |
| 85 | 654 | 735 | 1,194 | 1,469 | 4,052 |
| 86 | 1,062 | 1,119 | 988 | 950 | 4,119 |
| 87 | 1,352 | 1,100 | 1,346 | 1,783 | 5,581 |

The total annual sales of DFM from the Norfolk DFSP have shown a steady increase during the period of FY-82 through

FY-87. During these six years sales of DFM have risen 69 percent. The mean annual DFM sales from the Norfolk DFSP is 4,204.7 MBBL with a range of 2,287 MBBL. This upward trend in demand for DFM from the Norfolk DFSP makes forecasting for either annual or short-term wholesale bulk petroleum requirements difficult. While the CINCLANTFLT DFM budget has shown some variation, the Norfolk DFSP DFM sales have been significantly altered. This mismatch in operations could cause serious errors in forecasting for Second Fleet support levels.

Figure 2 shows the annual CINCLANTFLT Second Fleet DFM budget and the Norfolk DFSP DFM sales for the six years. Knowing the levels of the CINCLANTFLT DFM budget and the Norfolk DFSP DFM sales for the period of six years (FY-82 through FY-87) allows for the first step of the DFM sales requirements forecasting model to be completed. The first step is to establish the proportion of the CINCLANTFLT DFM budget that the Norfolk DFSP can be expected to represent. As can be seen from Table 4 the Norfolk DFSP has become a larger portion of the total CINCLANTFLT Second Fleet DFM budget in six years, increasing from 46 to 71 percent.

The question which also arises is "what will the sales percentage be for FY-88 and beyond?" The first reaction is that FY-88 sales should be 92 percent of the budget, given the rate of increase each year since 1984. In FY-89 it would be 100 percent. However, this will probably not

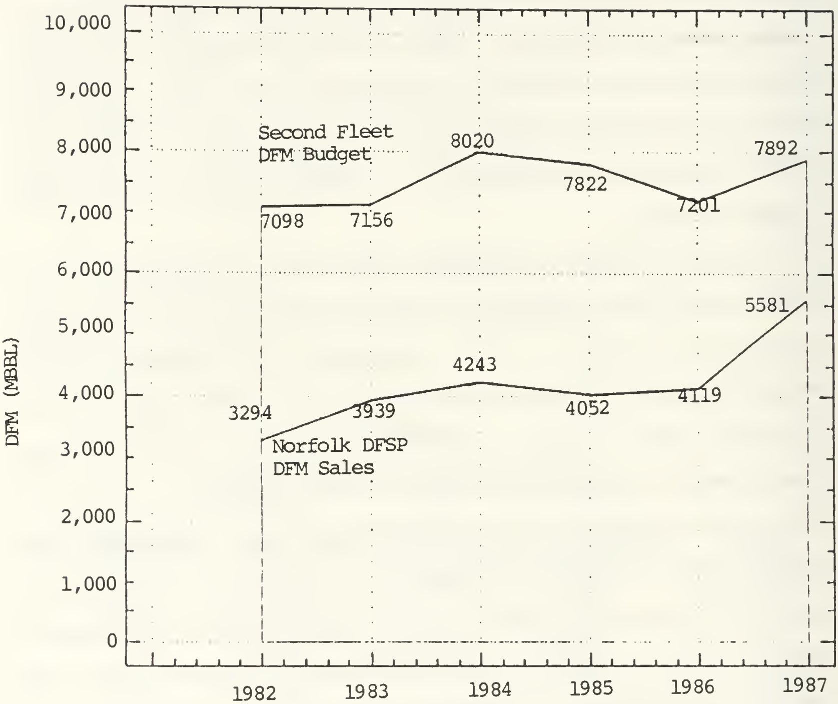


Figure 2. Second Fleet DFM Budget
Norfolk DFSP DFM Sales

TABLE 4

NORFOLK DFM SALES, PERCENT OF SECOND FLEET DFM BUDGET

| Year | Norfolk Sales (MBBL) | Second Fleet Budget (MBBL) | Sales as a Percent of Budget |
|---|---|---|---|
| 82 | 3,294 | 7,098 | 46.4074 |
| 83 | 3,939 | 7,156 | 55.0447 |
| 84 | 4,243 | 8,020 | 52.9052 |
| 85 | 4,052 | 7,822 | 51.8026 |
| 86 | 4,119 | 7,201 | 57.2004 |
| 87 | 5,581 | 7,892 | 70.7172 |

happen because the Second Fleet DFM budget is not expected to increase much in the next two years and the Norfolk portion of the CINCLANTFLT DFM budget could not be expected to continue to increase without exceeding its storage capacity. As a consequence, to evaluate the best fit of the Norfolk DFSP DFM sales to the CINCLANTFLT Second Fleet DFM budget and Norfolk's storage capacity the author ran the proposed requirements forecasting model at five "percentage of budget" levels (60, 65, 70, 75, and 80 percent) corresponding to the FY-87 level and five and ten percent below and above. The different levels of requirements forecasting were then compared to the actual Norfolk DFSP DFM storage capacity. The percentage levels, mean

inventories, and minimum levelsfrom the forecasts are shown in Table 5.

TABLE 5

SIM LEVELS INVENTORY PERFORMANCE

| Percent of CINCLANT DFM Budget | Mean Inventory | Maximum Inventory | Minimum Inventory |
|---|---|---|---|
| 60 | 1,264 MBBL | 1,405 MBBL | 1,063 MBBL |
| 65 | 1,388 | 1,517 | 1,234 |
| 70 | 1,477 | 1,634 | 1,348 |
| 75 | 1,577 | 1,750 | 1,403 |
| 80 | 1,671 | 1,884 | 1,460 |

Table 5 shows the proposed forecasting procedure when run with the 60, 70, 75, and 80 percent of CINCLANTFLT DFM budget resulted in either insufficient or excessive mean inventories. Excessive variance under and over the maximum authorized depleted or built stocks. The 70, 75, and 80 percent levels resulted in stock levels beyond the ability of the terminal to receive or store them. Based on these reasons the 65 percent ratio of Norfolk DFSP DFM sales to CINCLANTFLT DFM budget will be assumed. Its value is 65 percent of 7,699 MBBL, or 5,004 MBBL.

## D. SEASONALITY INDICES

The mismatch between the quarterly sales and budget allocations shown in Figure 2 suggests that the even production schedule of one-twelfth of the annual demand per month will cause problems. The quarterly sales totals could be used to develop a forecasting model. However, demand information would be lost that is needed for comparison to the even monthly production schedules. Thus, the monthly demands were next examined. Table 6 shows the past five years of monthly demand and, at the bottom of each column, the five-year average demand by month. The average value below the "Total" column is the average monthly sales over all years.

TABLE 6

NORFOLK DFSP
MONTHLY SEASONALITY INDEX (MONTHLY SALES)

| FY | OCT | NOV | DEC | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 82 | 549 | 220 | 234 | 160 | 346 | 243 | 408 | 244 | 234 | 350 | 218 | 88 | 3,294 |
| 83 | 179 | 215 | 268 | 432 | 298 | 284 | 413 | 416 | 298 | 358 | 386 | 392 | 3,939 |
| 84 | 231 | 293 | 193 | 548 | 317 | 238 | 290 | 266 | 508 | 396 | 491 | 272 | 4,043 |
| 85 | 296 | 56 | 302 | 286 | 204 | 245 | 455 | 438 | 301 | 465 | 696 | 308 | 4,052 |
| 86 | 339 | 380 | 343 | 394 | 223 | 502 | 406 | 299 | 483 | 396 | 385 | 169 | 4,319 |
| 87 | 499 | 395 | 458 | 364 | 207 | 529 | 373 | 546 | 427 | 663 | 624 | 496 | 5,581 |
| $\bar{X}$ | 349 | 260 | 300 | 364 | 266 | 340 | 391 | 368 | 375 | 438 | 467 | 288 | 350.5 |

A definite seasonal pattern appears when these averages are considered. February is usually a low demand month and July and August are consistently high demand months. September, November and December are also low demand months. The reasons for the low demand months appear obvious. September is the end of the fiscal year and the operating tempo of the Second Fleet declines because it is running out of money. November and December are low because of the holiday season. February is low because it has the most severe of the winter weather. As winter turns to spring and spring to summer the operating tempo increases, peaking in August. A good forecasting model needs to incorporate these seasonal influences on operating tempo.

In forecasting models for seasonality effects a "seasonality index" is computed for each month. To compute the seasonality index for a specific month the mean monthly sales is divided by the monthly mean spanning all months for all six years. For October the seasonality index (S.I.) would be the mean month sales 349 divided by the average monthly sales over all years of 350.5, or S.I. = 349/350.5 = .9957. This can be interpreted to mean that, on the average, DFM sales in the month of October can be expected to be 99.57 percent of the straight monthly prorata. All 12 monthly seasonality indices for the DFM requirements forecasting model are shown in the second column of Table 7.

TABLE 7

SIM INDICES, MONTHLY SALES FORECASTS

| Month | Index | Forecasts for Monthly Demand (MBBL) for FY-88 |
|---|---|---|
| October | .9957 | 415.2359 |
| November | .7418 | 309.3522 |
| December | .8559 | 356.9352 |
| January | 1.0385 | 433.0847 |
| February | .7589 | 316.4834 |
| March | .9700 | 404.5182 |
| April | 1.1155 | 465.1960 |
| May | 1.0499 | 437.8389 |
| June | 1.0699 | 446.1794 |
| July | 1.2496 | 521.1196 |
| August | 1.3324 | 555.6496 |
| September | .8217 | 342.6728 |

## E. MONTHLY FORECASTS

From the 65 percent annual budget value, the average monthly demand, ignoring seasonality, can be computed. The result is 417.0291 MBBL per month. The final step is to multiply this monthly forecast by the seasonality indices. For example, the October S.I. value is .9957. The product, 417.0291 x 0.9957 = 415.2359 MBBL, is the forecast for October of FY-88. The last column of Table 7 presents the forecasts for all 12 months of FY-88.

## F. THE FORECASTING MODEL

The mathematical statement of the monthly forecast for DFM at the Norfolk DFSP is:

$$F_i = N_R[CB/12]\bar{X}_i/\bar{X} ,$$

where:

$F_i$ = the forecast of sales for month i;

$N_R$ = the fraction of the annual Second Fleet DFM budget which is assumed for the Norfolk DFSP;

CB = the annual Second Fleet DFM budget;

12 = converts CB to the monthly prorata budget;

$\bar{X}_i$ = the average sales for month i for the last n years;

$\bar{X}$ = the average sales over all months for the last n years;

The ratio $\bar{X}_i/\bar{X}$ is the seasonality index for month i.

For the forecasts presented in Table 7, the $N_R$ value was 0.65, CB was 7,699 MBBL, $\bar{X}$ was 350.5 MBBL, and n was 6 years. The $\bar{X}_i$ values for each month were shown in Table 6 at the bottom of each month's column.

## G. SUMMARY

The proposed forecasting model presented in this chapter has assumed expected annual DFM sales for the Norfolk DFSP to be a percentage of the annual CINCLANTFLT Second Fleet DFM budget allocation. This quantity of demand was then

prorated as a constant demand requirement over 12 months of the new fiscal year. The seasonality indices then convert the prorata amount into individual monthly forecasted DFM requirements.

Calculation of a seasonality index results in an estimate of future operational levels based on averaging of historic data. Results are not meant to be interpreted as exact demand levels resulting from future operational tempos, but to be the best expected or average estimate. Norman Gaither explains this as follows:

> ...when time series analysis generates forecasts for future periods, we must recognize that these are only estimates and that the actual...sales to be subsequently realized may differ substantially from the forecasts. In fact, no one would be more surprised than the forecaster if they hit the forecasts on the nose...the uncertainty surrounding this estimate is demonstrated by showing the forecasts as a mean or central tendency at a frequency distribution of all of the possible values of...sales during (the) time period.... [Ref. 21:p. 87]

The next chapter will compare the performance of this proposed model with the current forecasting model using actual demand data from FY-88.

# IV. FORECASTS RESULTS AND IMPLICATIONS

## A. INTRODUCTION

This chapter will compare the current Norfolk DFSP forecasts, the forecasts as calculated using the proposed seasonality index model (SIM), and actual sales of DFM in FY-88. In the comparison the impact on terminal operations and statistical accuracy of the forecasting methods will be examined. As shown in the previous chapter the SIM forecasting model provides the monthly forecasted levels of DFM requirements for an entire fiscal year (12 months).

## B. EVALUATING THE BUDGET PERCENTAGE

Due to the upward trend in DFM sales for the Norfolk DFSP from fiscal year 1982 to 1987 the SIM model was tested at five levels: 60, 65, 70, 75 and 80 percent of the FY-88 CINCLANTFLT Second Fleet DFM budget. Assumptions made during the test of the forecasting model were:

- The maximum DFM storage capacity for the Norfolk DFSP is 1500 MBBL.
- The maximum authorized DFM inventory level (stockage objective) for the Norfolk DFSP is 1350 MBBL.
- All forecasted DFM sales are received in the month for which the demand is forecasted.
- No inter-depot transfers of DFM between DFSPs is accomplished to offset inventory shortages.
- No spot purchase contracts are processed to cover the inventory shortages.

Both the 60 and 65 percent levels of budget give feasible solutions meeting the storage constraints. The 60 percent level did not maintain adequate stocks (authorized inventory level) to support customer demands and was therefore omitted from consideration. The mean monthly inventory was 1,264 MBBL. When run at the higher levels the SIM (70,75, and 80 percent) consistently violated the 1350 MBBL maximum authorized DFM inventory. The mean monthly inventories were 1,477 MBBL, 1,577 MBBL, and 1,671 MBBL. This resulted in a build-up of excessively high inventories, beyond the ability of the DFSP to receive and store the product. It also violated the assumption of 1500 MBBL maximum storage capacity. Accordingly, the data reported here are for the 65 percent level of budget. (The tabulated data for the forecasted levels of the seasonality index model and the Norfolk method are presented in Appendix A.)

## C. RESULTS

The DFSP Norfolk and the seasonality index model (SIM) forecasted DFM sales for FY-88 are shown in Table 8 along with the actual sales of DFM.

### 1. Norfolk DFSP Current Forecast

Figure 3 shows the DFM requirements and receipts, as forecasted by the Norfolk DFSP, by the dashed lines. Actual sales of DFM and assumed receipt of the forecasted requirements are shown by a solid line.

TABLE 8

NORFOLK AND SIM DFM FORECASTS VS ACTUAL SALES

NORFOLK DFSP FORECAST:

| 87 OCT | NOV | DEC | 88 JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | | | | |

SIM MODEL FORECAST:

| 87 OCT | NOV | DEC | 88 JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 415 | 309 | 357 | 433 | 317 | 405 | 465 | 438 | 447 | 521 | 555 | 342 |

NORFOLK DFSP ACTUAL DFM SALES:

| 87 OCT | NOV | DEC | 88 JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 329 | 452 | 202 | 363 | 450 | 555 | 408 | | | | | |

The result of using the existing DFM requirements forecasting method is that the on-hand DFM inventory position would steadily decline. The mean inventory over the seven-month test period would have been 1,118 MBBL. The DFM requirements forecasting method currently used by DFSP Norfolk would result in an inventory of 690 MBBL at the end of April, 1988 51.11 percent of the authorized inventory of 1350 MBBL. This would approximate the scenario which led to the DFM shortage on the East Coast during the spring-summer of 1987. A recent telephone conversation with inventory management personnel at the Norfolk DFSP has confirmed that the depot is indeed experiencing a decreasing DFM stock

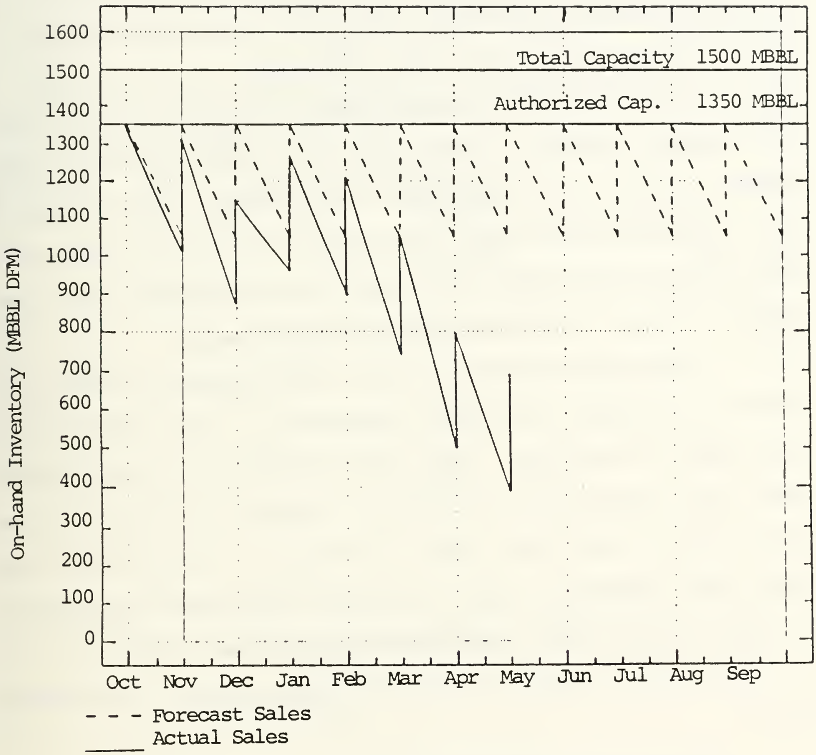


Figure 3. DFSP Norfolk DFM Forecast vs. Actual Sales

position during March-April 1988. On-hand DFM inventory as of 30 May, 1988 was 1,031 MBBL. [Ref. 22] The differnece between this inventory level and the 690 MBBL which would have resulted from the forecasting method was attributed to receipt of return-for-credit petroleum from afloat units.

### 2. Seasonality Index Model Forecasts

Figure 4 shows the results of the SIM forecasted DFM requirements based on 65 percent of the CINCLANTFLT DFM budget. Again, the forecasted requirements and receipt of the forecasted quantities are shown by a dashed line. The solid line shows actual DFM sales for the Norfolk DFSP and assumed receipt of SIM forecasted requirements.

Ordering according to the SIM forecasts allows for the DFM inventory stockage objective of 1350 MBBL to be maintained on average. The mean inventory over the seven-month test period was 1,388 MBBL. On-hand inventory at the end of April would have been 1291 MBBL 95.63 percent of the authorized inventory level. The DFM SIM forecasting model provides a much better estimate of the actual DFM sales for the first seven months of FY-88 than the current forecasting method.

### 3. Statistical Performance Measures

The error between the two DFM sales forecasting methods and actual DFM sales can be used to evaluate the model which better fits historic data. The monthly error

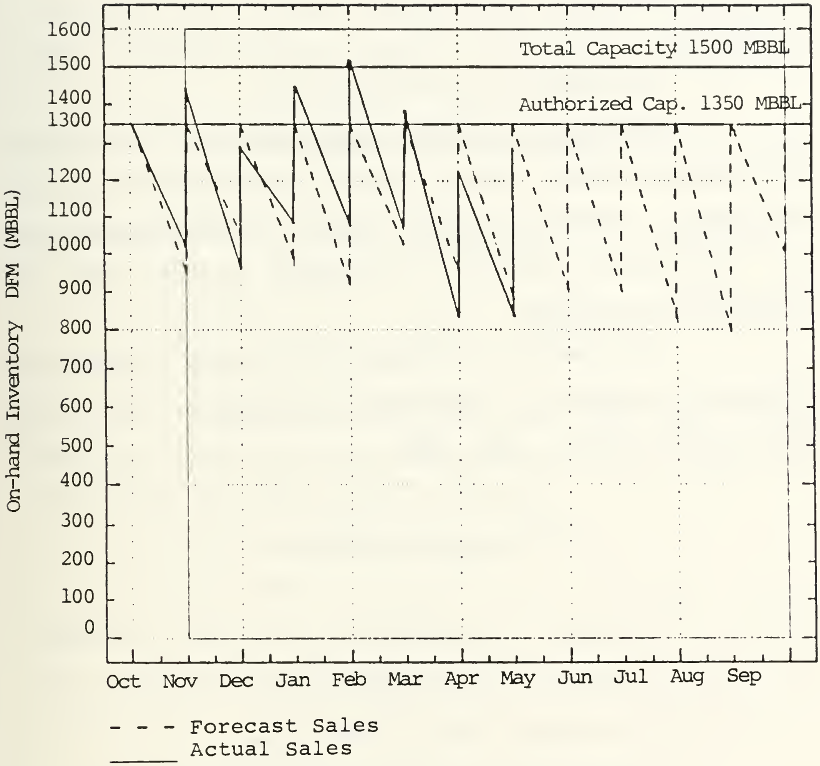


Figure 4. Seasonality Index Model DFM Sales Forecast

(actual minus forecast) is used to compute the following usual measures of a forecasting model performance.

- Mean Absolute Deviation (MAD).
- Mean Square Error (MSE).
- Net error.

a. Mean Absolute Deviation (MAD)

The MAD is computed from the sum of the absolute differences between actual and the forecasted levels of requirement. The MAD provides a measure of the magnitude of the forecasting error or variation between the two forecasting techniques.

Calculation of the MAD for the two requirements forecasting methods as explained by Berenson and Levine would be as follows: [Ref. 23]

$$MAD = \sum_{i=1}^{n} |y_i - \hat{y}_i|/n$$

where:

$y_i$ = Actual level of DFM sales.

$\hat{y}_i$ = Forecasted level of DFM sales.

$n$ = Number of periods over which the model is tested ($n = 7$).

For the Norfolk and seasonality index methods of forecasting DFM requirements the error $(y_i - \hat{y}_i)$ is given in Table 9.

TABLE 9

FORECASTING ERROR

| | OCT | NOV | DEC | JAN | FEB | MAR | APR |
|---|---|---|---|---|---|---|---|
| Norfolk | 29.47 | 152.49 | - 98.41 | 63.47 | 149.67 | 255.26 | 108.95 |
| SIM | -85.77 | 143.35 | -155.35 | -69.62 | 133.1 | 150.49 | -56.16 |

The MADs would be calculated from Table 9 as:

$$\text{Norfolk MAD: } \sum_{i=1}^{n} |y_i - \hat{y}_i|/n = 857.72/7 = 122.5314$$

$$\text{SIM MAD: } \sum_{i=1}^{n} |y_i - \hat{y}_i|/n = 793.84/7 = 113.4057$$

Thus the seasonality index (SIM) model provides the less unexplained absolute deviation and a better fit to the time series data based on the MAD.

b. Mean Squared Error (MSE)

The MSE is based on the principle of least squares. The MSE also provides an estimation of how much the forecasted requirements will vary from the actual levels of DFM sales. [Ref. 24:p.45] The formula for the MSE is:

$$\text{MSE} = \sum_{i=1}^{n} (y_i - \hat{y}_i)^2/n$$

Like the MAD, the MSE ignores the sign of the errors (they are eliminated by the squaring process). The MSE will emphasize the large deviations while the MAD treats

them more equally. Using the data from Table 9 the MSE for the Norfolk and seasonality index forecasting models follows:

$$\text{Norfolk MSE: } \sum_{i=1}^{n} (y_i - \hat{y}_i)^2/n = 137{,}263.53/7 = 19{,}609.08$$

$$\text{SIM MSE: } \sum_{i=1}^{n} (y_i - \hat{y}_i)^2/n = 100{,}403.07/7 = 14{,}343.30$$

Again, the SIM provides the better forecast for DFM requirements at the Norfolk DFSP.

c. Net Error

The Net Error is critical to the operation of a wholesale bulk petroleum inventory because excess quantities of petroleum can not be stored in excess warehouse space or in a receiving yard as can be done with other materials. Error in requirements forecasting can result in the inability of the terminal to receive the entire bulk petroleum cargo. This can require split-cargoes between DFSPs, excess in-transit time for POL cargoes, and increased personnel cost.

Calculation of the Net Error is as follows:

$$\text{Net Error} = \sum_{i=1}^{n} (y_i - \hat{y}_i),$$

This measure retains the sign of the errors.

From the data in Table 9 the Net Error for the Norfolk and seasonality index forecasting models can be calculated as follows:

$$\text{Norfolk Net Error:} \quad \sum_{i=1}^{n} (y_i - \hat{y}_i) = 660.90 \text{ MBBL}$$

$$\text{SIM Net Error:} \quad \sum_{i=1}^{n} (y_i - \hat{y}_i) = 60.04 \text{ MBBL}$$

As Berenson and Levine explain:

> ...if a model were to fit the past time-series data perfectly, then unexplained variation (net) would be zero. On the other hand, if a model were to fit the past time-series data poorly, the unexplained variation would be large. Thus, when comparing the adequacy of two or more forecasting models, the one with the minimum unexplained variation can be selected as most appropriate based on past fits of the given time series. [Ref. 23]

The SIM, over seven months, would produce only a 60.04 MBBL error (under-estimate) between actual and forecasted DFM requirements. An 11 to 1 ratio of net error between the two forecasting techniques indicates that the SIM is a much better model over the time period used for the evaluation.

## D. CONCLUSIONS

The final evaluation of the Norfolk and the SIM forecasting methods needs to consider the mission statement for the Norfolk DFSP:

> Serve as a Defense Fuel Support Point for the Defense Logistics Agency (DLA) owned bulk petroleum products in support of assigned units, Continental United States Navy activities, the Coast Guard, and other authorized

customers. Issue to other service activities as directed by the Defense Fuel Supply Center. [Ref. 25]

The support of operational Navy units makes the mission of the Norfolk DFSP critical to Second Fleet operational readiness. The lack of access to adequate petroleum assets can cause the failure of a battle group to perform its primary mission. A list of general procedures for developing a monthly sales forecast for any given site is provided as Appendix B.

1. <u>Norfolk DFSP DFM Forecasting Method</u>

The Norfolk DFSP method of forecasting for short-term DFM requirements is proving inadequate. The increasing trend in DFM sales, and the higher percentage of the CINCLANTFLT DFM annual budget that the Norfolk DFSP represents have contributed to the failure of the current forecasting method to accurately predict requirements. The DFM shortage problem which occurred during FY-87 can be expected to repeat unless corrective action is taken to regain the DFM inventory stock position. Delivery of adequate DFM during the high requirement months, from May through August, must be ensured.

The current forecasting method, if not corrected by receipt of product above the forecasted levels, would result in the following in FY-88:

- Decreased DFM stock position of 51 percent in May 1988. This low inventory position is just prior to the high requirement period of May-August.

- Need for inter-depot transfers of DFM inventories to offset the depleted inventory position at the Norfolk DFSP.

- Need for spot contract for procurement of DFM to meet emergent requirements when inventories for inter-depot transfers are not available or of insufficient quantity.

- Decreased East Coast CINCLANTFLT Area of Responsibility (AOR) coverage of War Reserve Requirements (PWRMR) at DFSPs.

- Decreased CINCLANTFLT operational readiness due to low DFM inventory position.

2. <u>Seasonality Index Model</u>

The seasonality index model (SIM) for forecasting short-term DFM requirements for the Norfolk DFSP appears to be meeting the operational commitments and should maintain the inventory stockage objective. If used in FY-88, at four times (OCT, DEC, JAN, FEB) the on-hand inventory for the Norfolk DFSP would have exceeded the authorized maximum stockage objective of 1350 MBBL. The SIM forecasting model remains feasible due to the depots ability to store petroleum up to a maximum safe fill level of 1,500 MBBL. The excess on-hand DFM inventory at the Norfolk DFSP would have reached its peak in January, 1988 when DFM inventories would have been 167.39 MBBL or 12.4 percent over the authorized depot inventory. The mean excess inventory for the four months would have been 96.305 MBBL or 7.1 percent. The excess inventory would have lasted, at the longest, two months. The cost of holding the excess DFM in inventory for such a short period is considered to be offset by the lack of cost associated with inter-depot transfers of inventories

or the spot procurement of DFM to cover emergent requirements.

Figure 3 shows that once during the model test period the SIM forecasting model would have resulted in an inventory position in excess of the maximum depot capacity for DFM (1500 MBBL). This would have occurred in January, 1988 at a level of 17.39 MBBL or 1.5933 percent above the terminal maximum storage capacity. This violation of the assumptions that the model was tested against is considered to be within the ability of the DFSP to adjust to without adversely impacting the production and delivery of DFM to the terminal. The 17.39 MBBL could be stored in the five percent safety level maintained above the depot maximum safe fill of 1,500 MBBL, or a scheduled delivery of DFM could be moved up or increased in quantity.

The SIM forecasts would have allowed the Norfolk DFSP to have a DFM inventory level at the end of April, 1988 of 95.6148 percent of authorized inventory capacity. Thus the DFSP would have entered the high requirements period (May-August) with nearly 100 percent of authorized inventory. If the seasonality index model based on 65 percent of the CINCLANTFLT annual DFM budget had been used the following should be the terminal implications:

- The inventory stockage objective would have been maintained.
- No inter-depot transfers of DFM would have been required.

- No spot procurement of DFM would have been required to cover emergent requirements.

- Improved lead time (12 months vs 4 months) to meet forecasted DFM requirements. Improved lead time could benefit refinery production and transportation scheduling.

- Lower operational, administrative, and procurement costs would have been incurred due to better requirements demand forecasting.

- Improved CINCLANTFLT operational readiness would be expected.

# V. REQUIREMENTS FORECASTING: SUMMARY, CONCLUSIONS, RECOMMENDATIONS

## A. SUMMARY

Chapter I presented the problem of short-term Marine Diesel Fuel (DFM) requirements forecasting procedures for support of the Norfolk DFSP. The increased proportion of Second Fleet DFM being provided by the Norfolk DFSP along with the inaccurate requirements produced by current forecasting techniques has acted to force acknowledgement of the problem. The chapter reviews the East Coast DFM shortage which occurred in 1987, and the command positions' analyses of the problem. Since at least the summer of 1986 the East Coast DFM wholesale bulk DFM requirements forecasts have not been accurately predicted. However, it appears that the forecasting problem did not start in 1986. Rather, it has been an ongoing problem which was finally brought to senior command attention by the mid-1987 DFM shortage problem.

The inability of the wholesale bulk petroleum management system to accomplish accurate or timely requirements forecasting has resulted in excess costs to the Defense Stock Fund (DSF). These costs were associated with the double handling of DFM for inter-depot transfers, uneconomical movement of product from remote petroleum refineries (Motor Oil Hellas, Athens, Greece), and high cost

spot procurements of petroleum to cover emergent requirements.

Chapter II reviewed the current literature governing the general military management of wholesale bulk petroleum. The responsibility for ICP and IMM petroleum management are clearly the responsibility of DLA. This includes the quantitative calculation of petroleum requirements. The DLA petroleum management responsibilities are assigned to DFSC and its subordinate DFRs. Unfortunately the calculation procedures and flow of forecasting data are not clearly identified in the government directives.

The Navy, through the Naval Petroleum Office, is responsible for the annual forecasting of Naval petroleum requirements. While this is being accomplished in both a timely and accurate manner, the annual forecast is not the source of the short-term requirements forecasting problem. Navy short-term requirement variations, due to changing fleet operational schedules, make specific requirement determination by locale extremely difficult, untimely, and inaccurate. An alternate method to short-term notification by the operating units is needed for wholesale requirements forecasting.

Chapter III presented a proposed method of calculating short-term wholesale bulk DFM requirements for the Norfolk DFSP. It is based on the CINCLANTFLT Second Fleet DFM budget allocation and the Norfolk DFSP monthly demand

seasonality index. The seasonality index model provides twelve monthly forecasts vice the current "slate" requirement for four months. Chapter IV compared the proposed and current forecasting methods both as to their effects on terminal storage capacity constraints and standard measures of effectiveness for forecasting models. The evaluation showed the seasonality index model to be a better petroleum requirements forecasting method.

## B. CONCLUSIONS

The current DFM requirements forecasting procedures are inadequate. The inability of the current requirements forecasting procedures to predict DFM sales levels extends back beyond the May-August 1987 shortage. Forecasting inaccuracies were found to exist at least back to August of 1986. Continued use of the current requirements forecasting procedures could be expected to result in an unstable DFM inventory position and another DFM shortage in July and August of FY-88.

The prorata production and resupply of DFSP Norfolk is inappropriate. The calculation of a seasonality index for the Norfolk DFSP shows significant variations between monthly requirements. A prorata delivery of DFM will not allow for these demand variances. In addition, the prorata forecasting and product delivery procedure will neither build inventory when required or allow for a carry-over of production quantities. This lack of flexibility will cause

the requirement for inter-depot transfer, or spot procurements of DFM.

Defense Stock Fund budget is inefficiently used. The inability of the current requirements forecasting procedures to predict short-term DFM requirements resulted in increased Defense Stock Fund (DSF) inventory costs. These costs were associated with inter-depot transfers (double hauling), cargo lifts from East Mediterranean refineries (Motor Oil Hellas), and spot procurements of DFM for coverage of emergent requirements.

Implementation of the seasonality index forecasting procedure should eliminate the requirement for these corrective actions and result in a savings to the DSF.

The seasonality index model (SIM) provides adequate demand forecasts. The seasonality index forecasting method should prove adequate for out years if the basic assumptions are maintained. The accuracy of the seasonality index forecasting method is considered accurate in the context of the historic data base it was built from. It does not account for requirements associated with full scale war or intense mobilization.

The Inspector General requirement for timely, accurate requirements forecasting has been met by SIM. The seasonality index forecasting method of determining short-term wholesale bulk DFM requirements has proven accurate during the seven-month test period. The monthly demand

errors were split three under and four over the requirements forecast. Net error over seven months was 60.04 MBBL, or 2.17 percent (vice a 660.9, 23.94) percent error for the current Norfolk forecasting method). The DOD-IG finding that timely, accurate forecasts be developed has been met.

## C. RECOMMENDATIONS

<u>Continue Seasonality Index Forecast Test for the Norfolk DFSP</u>. The proposed seasonality index forecasting procedure should be evaluated through the remainder of FY-88. At the end of the test period the association (percentage) of Norfolk DFSP sales to the CINCLANTFLT Second Fleet DFM budget, and the seasonality indices for the Norfolk DFSP should be reviewed. If still accurate at the end of the extended test period the seasonality index forecasting model should be implemented for FY-89.

<u>Expand application of the Seasonality Index Forecasting Procedure to other DFSPs</u>. If the proposed model is successfully tested, its use should be extended to other DFSPs. The process should be completed in three phases. First, the seasonality index forecasting model should be tested for other DFSPs supporting Second Fleet operations. This could include Charleston, Jacksonville, Puerto Rico, and Guantanamo Bay. Next, a parallel test for West Coast DFSPs supporting Third Fleet operations should be conducted. DFSPs which could be tested could include San Diego, Oakland, Puget Sound, and Pearl Harbor. Finally,

applicability of the seasonality index forecasting method to Sixth and Seventh Fleet operations should be considered. It could be tested against the Sixth and Seventh Fleet operations to ascertain if it, or a similar model, could assist in providing better requirements forecasts for support of deployed units.

Conduct more thesis research into petroleum management. Currently little research has been conducted into the area of petroleum management. The areas of inventory management, facilities management, maintenance, spare parts (COSBOL) levels, equipment standardization, slate procedures, depot Life-Cycle-Cost (LCC), and personnel training are potential areas of thesis research.

# APPENDIX A

## A SUMMARY OF FORECASTING METHODS

| | Norfolk Forecast | SIM FORECASTS 60 Per-Cent | 65 Per-Cent | 70 Per-Cent | 75 Per-Cent | 80 Per-Cent |
|---|---|---|---|---|---|---|
| MAD | 122.53 | 142.87 | 113.43 | 117.99 | 127.50 | 134.53 |
| MSE | 19,609 | 29,078 | 14,350 | 14,706 | 17,944 | 22,437 |
| Net Error | 660.90 | 915.55 | 60.09 | -130.29 | -355.43 | -563.19 |
| Mean Monthly Inventory | 1,118 | 1,264 | 1,388 | 1,477 | 1,577 | 1,671 |
| Standard Deviation | 111.7 | 126.95 | 127.96 | 135.38 | 154.87 | 136.53 |
| Ending Inventory 30 April 88 | 690 | 1,083 | 1,291 | 1,499 | 1,706 | 1,884 |
| Max over Authorized Inventory | n.a. | 33.7 | 132.6 | 232.4 | 358.2 | 456.9 |
| Max under Authorized Inventory | 606.0 | 277.0 | 87.7 | n.a. | n.a. | n.a. |

Norfolk DFSP DFM sales forecasts.

3,600 MBBL annual requirement

Prorata over 12 months = 3,600 / 12 = 300 MBBL

| Month | Actual Sales | Seasonality Index | Forecast Sales | Difference |
|---|---|---|---|---|
| Oct | 329.47 | 1.00 | 300 | 29.47 |
| Nov | 452.49 | 1.00 | 300 | 152.49 |
| Dec | 201.59 | 1.00 | 300 | - 98.41 |
| Jan | 363.47 | 1.00 | 300 | 63.47 |
| Feb | 449.67 | 1.00 | 300 | 149.67 |
| Mar | 555.26 | 1.00 | 300 | 255.26 |
| Apr | 408.95 | 1.00 | 300 | 108.95 |
| May | | 1.00 | 300 | |
| Jun | | 1.00 | 300 | |
| Jul | | 1.00 | 300 | |
| Aug | | 1.00 | 300 | |
| Sep | | 1.00 | 300 | |

Mean Absolute Deviation (MAD):

$$\begin{aligned} MAD &= 857.72/7 \\ &= 122.5314 \text{ MBBL} \end{aligned}$$

Mean Square Error (MSE):

$$\begin{aligned} MSE &= 137{,}263.5290/7 \\ &= 19{,}609.0756 \text{ MBBL} \end{aligned}$$

Net Error:

$$NE = 660.9 \text{ MBBL}$$

Range: 353.67 MBBL

Standard Deviation:

$$\begin{aligned} S^2 &= [(137{,}263.5290) - (660.9^2/7)]/6 \\ &= 12{,}477.5213 \end{aligned}$$

$$S = 111.7028 \text{ MBBL}$$

SIM run at 60 percent of CINCLANTFLT Second Fleet DFM Budget.

.60 x 7,699 MBBL = 3,419.4 MBBL

Prorata over 12 months = 3,419.4/12 = 284.95 MBBL

| Month | Actual Sales | Seasonality Index | Forecast Sales | Difference |
|---|---|---|---|---|
| Oct | 329.47 | .9957 | 283.7247 | 45.7453 |
| Nov | 452.49 | .7418 | 211.3759 | 241.1141 |
| Dec | 201.59 | .8559 | 243.8887 | - 42.2987 |
| Jan | 363.47 | 1.0385 | 295.9206 | 67.5494 |
| Feb | 449.67 | .7589 | 216.2486 | 233.4214 |
| Mar | 555.26 | .9700 | 276.4015 | 278.8585 |
| Apr | 408.95 | 1.1155 | 317.8617 | 91.0883 |
| May | | 1.0499 | 299.1690 | |
| Jun | | 1.0699 | 304.8680 | |
| Jul | | 1.2496 | 356.0735 | |
| Aug | | 1.3324 | 379.6674 | |
| Sep | | .8217 | 234.1434 | |

Mean Absolute Deviation (MAD):

MAD = 1000.0757/7
= 142.8680 MBBL

Mean Square Error (MSE):

MSE = 203,547.0745/7
= 29,078.1535 MBBL

Net Error:

NE = 915.4783 MBBL

Range: 321.1572 MBBL

Standard Deviation:

$S^2 = [(203,547.0745) - (915.4783^2/7)]/6$
$= 13,969.7382$

S = 118.1936 MBBL

SIM run at 65 percent of CINCLANTFLT Second Fleet DFM Budget.

.65 x 7,699 MBBL = 5,004.35 MBBL

Prorata over 12 months = 5,004.35/12 = 417.03

| Month | Actual Sales | Seasonality Index | Forecast Sales | Difference |
|---|---|---|---|---|
| Oct | 329.47 | .9957 | 415.2368 | - 85.7668 |
| Nov | 452.49 | .7418 | 309.3529 | 143.1371 |
| Dec | 201.59 | .8559 | 356.9360 | -155.3460 |
| Jan | 363.47 | 1.0385 | 433.0857 | - 69.6157 |
| Feb | 449.67 | .7589 | 316.4841 | 133.1859 |
| Mar | 555.26 | .9700 | 404.5191 | 150.7409 |
| Apr | 408.95 | 1.1155 | 465.1970 | - 56.2470 |
| May | | 1.0499 | 437.8398 | |
| Jun | | 1.0699 | 446.1804 | |
| Jul | | 1.2496 | 521.1207 | |
| Aug | | 1.3324 | 555.6508 | |
| Sep | | .8217 | 342.6736 | |

Mean Absolute Deviation (MAD):

$$\begin{aligned} MAD &= 794.0394/7 \\ &= 113.4342 \text{ MBBL} \end{aligned}$$

Mean Square Error (MSE):

$$\begin{aligned} MSE &= 100{,}447.9267/7 \\ &= 14{,}349.7038 \text{ MBBL} \end{aligned}$$

Net Error:

$$NE = 60.0884 \text{ MBBL}$$

Range: 305.5930 MBBL

Standard Deviation:

$$\begin{aligned} S^2 &= [(100{,}447.9267) - (60.0884^2/7)]/6 \\ &= 16{,}655.3541 \end{aligned}$$

$$S = 129.0556 \text{ MBBL}$$

SIM run at 70 percent of CINCLANTFLT Second Fleet DFM Budget.

.70 x 7,699 = 5,389.3 MBBL

Prorata over 12 months = 5,389.3/12 = 449.11 MBBL

| Month | Actual Sales | Seasonality Index | Forecast Sales | Difference |
|---|---|---|---|---|
| Oct | 329.47 | .9957 | 429.7983 | -100.3283 |
| Nov | 452.49 | .7418 | 333.1498 | 119.3402 |
| Dec | 201.59 | .8559 | 384.3932 | -182.8032 |
| Jan | 363.47 | 1.0385 | 466.4007 | -102.9307 |
| Feb | 449.67 | .7589 | 340.8296 | 108.8404 |
| Mar | 555.26 | .9700 | 435.6367 | 119.6233 |
| Apr | 408.95 | 1.1155 | 500.9822 | - 92.0322 |
| May | | 1.0499 | 471.5206 | |
| Jun | | 1.0699 | 480.5028 | |
| Jul | | 1.2496 | 561.2079 | |
| Aug | | 1.3324 | 598.3942 | |
| Sep | | .8217 | 369.0337 | |

Mean Absolute Deviation (MAD):

MAD = 825.8983/7
= 117.9855 MBBL

Mean Square Error (MSE):

MSE = 102,945.4825/7
= 14,706.4975 MBBL

Net Error:

NE = -130.2905 MBBL

Range: 302.4265 MBBL

Standard Deviation:

$S^2 = [(102,945.4825) - (130.2905^2/7)]/6$
$= 16,753.3991$

S = 129.4349 MBBL

SIM run at 75 percent of CINCLANTFLT Second Fleet DFM Budget.

.75 x 7,699 MBBL = 5,774.25 MBBL

Prorata over 12 months = 5,774.25/12 = 481.19

| Month | Actual Sales | Seasonality Index | Forecast Sales | Difference |
|---|---|---|---|---|
| Oct | 329.47 | .9957 | 479.1209 | -149.6509 |
| Nov | 452.49 | .7418 | 356.9467 | 95.5433 |
| Dec | 201.59 | .8559 | 411.8505 | -210.2605 |
| Jan | 363.47 | 1.0385 | 499.7158 | -136.2458 |
| Feb | 449.67 | .7589 | 365.1751 | 84.4949 |
| Mar | 555.26 | .9700 | 466.7543 | 88.5057 |
| Apr | 408.95 | 1.1155 | 536.7674 | -127.8174 |
| May | | 1.0499 | 505.2014 | |
| Jun | | 1.0699 | 514.8252 | |
| Jul | | 1.2496 | 601.2950 | |
| Aug | | 1.3324 | 641.1376 | |
| Sep | | .8217 | 395.3938 | |

Mean Absolute Deviation (MAD):

$$\begin{aligned} MAD &= 892.5185/7 \\ &= 127.5026 \text{ MBBL} \end{aligned}$$

Mean Square Error (MSE):

$$\begin{aligned} MSE &= 125{,}606.2447/7 \\ &= 17{,}943.7492 \text{ MBBL} \end{aligned}$$

Net Error:

$$NE = -\ 355.4307 \text{ MBBL}$$

Range: 305.8038 MBBL

Standard Deviation:

$$\begin{aligned} S^2 &= [(125{,}606.2447) - (355.4307^2/7)]/6 \\ &= 17{,}926.4936 \end{aligned}$$

$$S = 133.8899 \text{ MBBL}$$

SIM run at 80 percent of CINCLANTFLT Second Fleet DFM Budget.

.80 x 7,699 MBBL = 6,159.2 MBBL

Prorata over 12 months = 6,159.2 / 12 = 513.27 MBBL

| Month | Actual Sales | Seasonality Index | Forecast Sales | Difference |
|---|---|---|---|---|
| Oct | 329.47 | .9957 | 511.0629 | -181.5929 |
| Nov | 452.49 | .7418 | 380.7437 | 71.7463 |
| Dec | 201.59 | .8559 | 439.3078 | -237.7178 |
| Jan | 363.47 | 1.0385 | 533.0309 | -169.5609 |
| Feb | 449.67 | .7589 | 389.5206 | 60.1494 |
| Mar | 555.26 | .9700 | 497.8719 | 57.3881 |
| Apr | 408.95 | 1.1155 | 572.5527 | -163.6027 |
| May | | 1.0499 | 538.8822 | |
| Jun | | 1.0699 | 549.1476 | |
| Jul | | 1.2496 | 641.3822 | |
| Aug | | 1.3324 | 683.8809 | |
| Sep | | .8217 | 421.7540 | |

Mean Absolute Deviation (MAD):

$$\begin{aligned} MAD &= 941.6944/7 \\ &= 134.5278 \text{ MBBL} \end{aligned}$$

Mean Square Error (MSE):

$$\begin{aligned} MSE &= 157{,}061.0466/7 \\ &= 22{,}437.2924 \text{ MBBL} \end{aligned}$$

Net Error:

$$NE = -\ 563.1905 \text{ MBBL}$$

Range: 309.4641 MBBL

Standard Deviation:

$$\begin{aligned} S^2 &= [(157{,}061.0466) - (-563.1905^2/7)]/6 \\ &= 18{,}624.8521 \end{aligned}$$

$$S = 136.4729 \text{ MBBL}$$

## APPENDIX B

### GENERAL PROCEDURES FOR MONTHLY SIM FORECASTS

General procedures for developing a monthly sales forecast for any given petroleum terminal site.

1. Get major customer's (i.e., CINCLANTFLT) historic petroleum budget for the product to be forecast.

    a. Get as many past years as possible. This will increase the confidence level of the resulting association to be developed in step 3.

2. Get petroleum terminal historic sales data. The same number of years of data is required as obtained for the petroleum budget.

    a. Monthly sales data is needed to construct a monthly seasonality index.

    b. Annual sales data is needed to establish the percentage relationship between the terminal sales and the customer's budget.

3. Compare customer's annual budget and terminal annual sales data to establish percentage association. The terminal sales for each year should be divided by the customer's budget for the same year. Evaluate for consistency or trends in the relationship.

    a. If the percentage is consistent over the years reviewed then this is the level of association to assume for the next fiscal year. If the percentage relationship between terminal sales and the customer's petroleum budget indicates an inconsistent or trending pattern then a range of forecasts must be calculated.

4. Calculate the product of the customer's petroleum budget and the chosen percentage level as the annual sales forecast for the petroleum terminal. Equally subdivide the annual petroleum sales forecast over 12 months.

5. Calculate the monthly seasonality index for the petroleum terminal.

6. Multiply the prorata monthly customer's sales forecast from Step 4 by the terminal monthly seasonality index. This will provide the expected monthly sales forecasts.

    a. For each percentage value assumed in Step 3, plot the past fiscal year's demand and replenishment curves as described in Chapter IV to see if any violate the storage capacity of the terminal site. Discard those which violate capacity constraints by more than the product safety capacity.

7. Calculate the Mean Absolute Deviation (MAD), Mean Squared Error (MSE), and Net Error to evaluate the performance of the forecasting model.

    a. Calculate the MAD for each level of percentage association tested (step 3.a). The lowest MAD indicates the best association between the budget and forecasted sales.

    b. Calculate the MSE for each level of percentage of association tested. The lowest MSE indicates the best association between the budget and forecasted sales.

    c. Calculate the Net Error for each level of percentage of association tested. The Net Error should tend to zero over time. The lowest net error indicates the best association between the budget and forecasted sales.

8. The percentage association which results in the lowest MAD, MSE, and Net Error is the level of sales which should be forecasted for support of the customer for the next fiscal year.

    a. The forecast for sales comes from step 6 for the selected percentage association.

The sales of petroleum to the budgeting customer must be evaluated monthly to ensure that the model is adequately supporting actual levels of demand. This does not mean that there will be no error between the model and actual sales. It means that the errors should occur for both over and under estimation, tending to a zero error over time.

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